CEE 371	May 14, 2009

Final Exam

Closed Book, two sheets of notes allowed
Please answer questions 3, 6 and 7. In addition, answer either question 1 or 2, and answer either question 4 or 5. The total potential number of points is 100. Show all work. Be neat, and box-in your answer.

Please grade the following questions:

1	or	2
4	or	5

Circle one from each row. You must answer 3, 6 and 7

1) (**15 pts**) A 10 inch diameter sanitary sewer is designed such that it has a flowing full velocity of 3.5 ft/s. A Manning's roughness coefficient value of 0.013 is assumed. The 10 inch sewer exits sewer manhole (SMH) 1 at an invert out elevation of 98.30 ft.

a) (**9 pts**) What is the invert elevation of the sewer as it enters SMH 2 which is located 285 ft downstream of SMH 1?

b) (**3 pts**) Does the sewer have capacity for a design flow of 0.8 MGD? Show quantitatively.

c) (**3 pts**) What is the desired minimum velocity in the pipe at the design flow? Why?

2) (**15 pts**) Sewer Basics

a) (**3 pts**) Combined sewers were designed to collect and convey what two types of flows to a wastewater treatment plant?

b) (**3 pts**) What is a CSO?

c) (**3 pts**) List 3 different materials that sewers can be made of.

d) (**6 pts**) List 3 conditions or situations that require use of a manhole in a sewer system.

3) (**4 pts**) What does the term "I/I" mean with respect to flow in sewers? Explain.

4) (**15 pts**) Draw (boxes, lines, arrows) and label (words) a schematic diagram showing <u>all the typical treatment processes and liquid flow paths</u> in an entire conventional municipal wastewater treatment plant using <u>complete-mix activated sludge</u> to provide secondary treatment. Also show and label the residuals produced by certain processes.

5) Biotreatment Basics and Regulations (**15 pts**)

a) (**5 pts**) Activated sludge is an example of a ________________________ type of biological wastewater treatment process, while a trickling filter or a biological tower is an example of a ___________________________ type of biological WW treatment process.

b) (4 **pts**) Name three different types of activated sludge systems and explain how they are different in just a few words

c) (**6 pts**) In 1972 major federal legislation was enacted that later became known as the Clean Water Act. That legislation established water quality goals for the nation's waters and minimum requirements for secondary wastewater treatment.
i) What is the name of the permit system for controlling wastewater discharges?
ii) What are the quantitative requirements for BOD_5 and SS in wastewater discharges from secondary WWTPs?

6) (**40 pts**) You have been selected to design a secondary wastewater treatment plant (WWTP) for Phishville, a Vermont municipality of 15,000 people which has some industry (Ben & Jerry's) that discharges wastewater to the municipal sewer system. The average daily wastewater flow is 2.1 MGD and the raw sewage entering the WWTP has an average BOD_5 of 240 mg/L and average suspended solids of 260 mg/L.

a) (**4 pts**) If the average domestic per capita sewage flow is 115 gpcd, what is the average flow of the industrial wastewater (in MGD)?

b) (**6 pts**) If the average BOD_5 load from the domestic sewage is 0.18 lbs/capita-day, what is the average daily BOD_5 loading (in lbs/day) from the industrial wastewater? What is the population equivalent to this BOD_5 loading?

c) (**4 pts**) The wastewater is treated in two parallel primary sedimentation tanks. What is the diameter of each tank for a design overflow rate of 600 gpd/ft^2 at average flow?

d) (**6 pts**) Primary treatment achieves 65% suspended solids removal and 35% BOD_5 removal. What are the average BOD_5 and SS concentrations (mg/L) and daily loadings (1b/day) entering the secondary treatment process?

e) (**20 pts**) A complete mix activated sludge process is to be used for biological treatment. Assume average flow conditions and the primary treatment performance as in part d) above. Assume the following for the activated sludge process:

- Plant effluent BOD_5 of 12 mg/L
- Biomass yield (Y) of 0.54 kg biomass / kg BOD
- Endogenous decay rate (k_d) = 0.05 day^{-1}
- Solids Retention Time (θ_C) = 8 days
- MLVSS concentration in the aeration tank (X) of 2700 mg/L
- Waste and recycle solids concentration (X_R) of 12,000 mg/L

Make calculations based on a single train, i.e., total plant flow for the following:

i) Determine the aeration tank volume in cubic meters.
ii) Determine the design hydraulic detention time, in hours.
iii) Determine the mass (dry) and volumetric rates of secondary sludge wasted (kg/day, m^3/day).
iv) Determine the sludge recycle (return) flow rate in m^3/day and the recycle ratio.
v) Determine the food to microorganism ratio.

7) (**26 pts**) More work for your firm! Phishville, the municipality from Problem 6, has hired you to consider their drinking water supply and treatment needs for the future. Assume that average industrial water demand is the same now and in the future, and is equal to the industrial wastewater flow you determined for Problem 6, part a).

a) (**4 pts**) If the average domestic per capita water demand is 110 gpcd, and the population is projected to grow by 350 people per year, estimate the average daily water demand (in MGD) for Phishville in 20 years.

b) (**12 pts**) The drinking water source for Phishville is a reservoir and the water is treated by conventional processes. The water surface elevation in the clear well at the end of the treatment plant is 160 ft. In order to supply adequate pressure for the municipality, the hydraulic grade line (HGL) of the water system must be at elevation 330 ft. Treated water is pumped through 2 miles of 16 inch diameter ductile iron pipe (C_{HW} = 120) to the water distribution system. If the ratio of maximum day demand to average day demand is 1.5, what is the required pump power (in horsepower) to supply $Q_{max\ day}$ in the future (20 years from now)?

c) (**4 pts**) A developer wants to build homes in an undeveloped area of Phishville adjacent to the existing distribution system. The ground elevations are 300 to 310 ft in this area. Can the current water system provide adequate pressure for this development? Show quantitatively.

d) **(6 pts)** What component of the Phishville drinking water system is designed to provide water in the event of a short-term, or emergency, loss of the water source? What two other types of water demands are considered in the design of this component of the water system?

Good stuff to know

<u>Conversions</u>

7.48 gallon = 1.0 ft^3 1 gal = 3.7854×10^{-3} m^3

1 MGD = 694 gal/min = 1.547 ft^3/s = 43.8 L/s

1 ft^3/s = 449 gal/min

g = 32 ft/s^2

W=γ = 62.4 lb/ft^3 = 9.8 N/L

1 hp = 550 ft-lbs/s = 0.75 kW

1 mile = 5280 feet 1 ft = 0.3048 m

1 watt = 1 N-m/s

1 psi pressure = 2.3 vertical feet of water (head)

At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s

Water Properties:

At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s , $\mu = 2.359 \times 10^{-5}$ $lb\text{-}sec/ft^2$, $\gamma = 62.4$ lb/ft^3

At 10 ºC, $\nu = 1.306 \times 10^{-6}$ m^2/s , $\mu = 1.307 \times 10^{-3}$ kg/m-s , $\rho = 999.7$ kg/m^3

PHYSICAL AND CHEMICAL CONSTANTS

Avogadro's number	$\mathcal{N} = 6.022 \times 10^{23}\ \text{mol}^{-1}$
Elementary charge	$e = 1.602 \times 10^{-19}\ \text{C}$
Gas constant	$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$
	$= 1.987\ \text{cal mol}^{-1}\ \text{K}^{-1}$
	$= 0.08205\ \text{L atm mol}^{-1}\ \text{K}^{-1}$
Planck's constant	$h = 6.626 \times 10^{-34}\ \text{J s}$
Boltzmann's constant	$\mathbf{k} = 1.381 \times 10^{-23}\ \text{J K}^{-1}$
Faraday's constant	$F = 9.649 \times 10^{4}\ \text{C mol}^{-1}$
Speed of light	$c = 2.998 \times 10^{8}\ \text{m s}^{-1}$
Vacuum permittivity	$\varepsilon_0 = 8.854 \times 10^{-12}\ \text{J}^{-1}\ \text{C}^2\ \text{m}^{-1}$
Earth's gravitation	$g = 9.806\ \text{m s}^{-2}$

CONVERSION FACTORS

1 cal	= 4.184 joules (J)
1 eV/molecule	= 96.485 kJ mol^{-1}
	= 23.061 kcal mol^{-1}
1 wave number (cm^{-1})	= 1.1970×10^{-2} kJ mol^{-1}
1 erg	= 10^{-10} kJ
1 atm	= 1.01325×10^{5} Pa
1 Å	= 10^{-10} m
1 L	= 10^{-3} m^3

PROPERTIES OF WATER

T(°C)	ρ, Density ($\text{kg} \cdot \text{m}^{-3}$)	μ Viscosity ($\text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$)	σ, Surface Tension against Air ($\text{J} \cdot \text{m}^{-2}$)	ε Dielectric Constant ($\text{C} \cdot \text{V}^{-1} \cdot \text{m}^{-1}$)	pK_w, Ionization Constant ($\text{mol}^2 \cdot \text{L}^{-2}$)
0	999.868	0.001787	0.0756	88.28	14.9435
5	999.992	0.001519	0.0749	86.3	14.7338
10	999.726	0.001307	0.07422	84.4	14.5346
15	999.125	0.001139	0.07349	82.5	14.3463
20	998.228	0.001002	0.07275	80.7	14.1669
25	997.069	0.0008904	0.07197	78.85	13.9965
30	995.671	0.0007975	0.07118	77.1	13.8330

SI PREFIXES

Multiplication Factor	Prefix	Symbol	Multiplication Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
10^{2}	hecto	h	10^{-12}	pico	p
10^{1}	deka	da	10^{-15}	femto	f
10^{-1}	deci	d	10^{-18}	atto	a